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13. ABSTRACT *(Maximum 200 Words)*

Meta-management using broker concept has been increasingly accepted for interconnecting multiple Picture Archiving and Communication Systems (PACS) via global network in the Integrated Healthcare Enterprise (IHE). An example of multiple PACS integration is the planned project entitled "U.S. Army Virtual Radiology Environment (USAVRE)", announced by the U.S. military. We propose methods to enhance this broker-based meta-management approach in the aspects of interchange and information protection for medical images within an IHE.

The proposed project will use our existing asynchronous transfer mode (ATM) network and the being implemented next generation internet (NGI) to interconnect four hospitals with different clinical settings in Northern California. Our study consists of two major components. The first component is to develop a meta medical image archive (MMIA) prototype system as the testbed to simulate the meta-management of multiple PACS in an IHE environment. The second component is to implement a comprehensive information protection infrastructure based on reliability, security, and authenticity for multi-PACS medical images on top of MMIA. We will evaluate the two components in both technical and clinical aspects. Results from this study will provide important guidelines in multiple PACS integration to support healthcare delivery systems for the IHE.

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Introduction

Picture Archiving and Communication Systems (PACS) provide the means to acquire, store, and manage medical images for use in clinical review and diagnosis. The Digital Imaging and Communications (DICOM) standard for the communication of images permits implementation of a PACS that interconnects multi-vendor medical imaging equipment capable of delivering reliable and efficient services in support of patient care within their domains. Deployment of commercial PACS in hospital settings has grown at a double-digit rate in recent years. However, when a patient accesses care at multiple institutions, the PACS in those facilities need to be integrated to provide cross-system interoperability. One solution to address problems with this integration that stems from different information infrastructures at different institutions, is to use a meta-manager as a systems broker to interconnect the different databases. A primary concern of the broker implementation approach is how to identify and protect patient information across the enterprise-wide medical imaging infrastructure, since in many occasions this is out of the security domain of an individual PACS in a local hospital setting. The purpose of this project is to develop a Meta Medical Image Archive (MMIA) test-bed that interconnects multiple PACS and permits issues such as reliability, security, and image authenticity to be addressed and explored.

Body

Task Accomplishments:

Design and implementation of a Meta Medical Image Archive (MMIA) test-bed (Task 3).

a) Hardware developments

Principal efforts during the second year of the project have been to design and implement an MMIA test-bed with appropriate software tools. The current component configuration is shown in Figure 1. Software development has proceeded using the PCI based E450/ Solaris 8 system with the intent of porting this to the E3000. However, current failover software requires that all computers in a cluster have the same bus structure. Thus, in order to implement failover components, the E3000 will need to be replaced. A 100-slot DVD-RAM jukebox has been exchanged for a 300-slot jukebox to increase the capacity of the long-term image archive. This new jukebox is equipped with a media flipper that can operate double-sided, 9.4-GB DVD-RAM media. The jukebox has been successfully connected to the Sun E450 host computer.

The test cluster connects the MMIA archive server to two commercial image archive systems, IMPAX from Agfa Medical Imaging and eFilm from Merge Technologies, Inc. This test-bed can be used for testing the communication of images among these three archive systems. b) Software developments

Installation of Digital Imaging and Communications in Medicine (DICOM) standard software on the MMIA has been accomplished and the development of the broker software has progressed. The DICOM software from the Mallinckrodt Institute of Radiology's CTN 3.0 utility libraries was installed to serve as an application programming interface (API) to support MMIA's image communication and storage applications. Design functions of the MMIA are shown in Figure 2. The following software is currently operable.

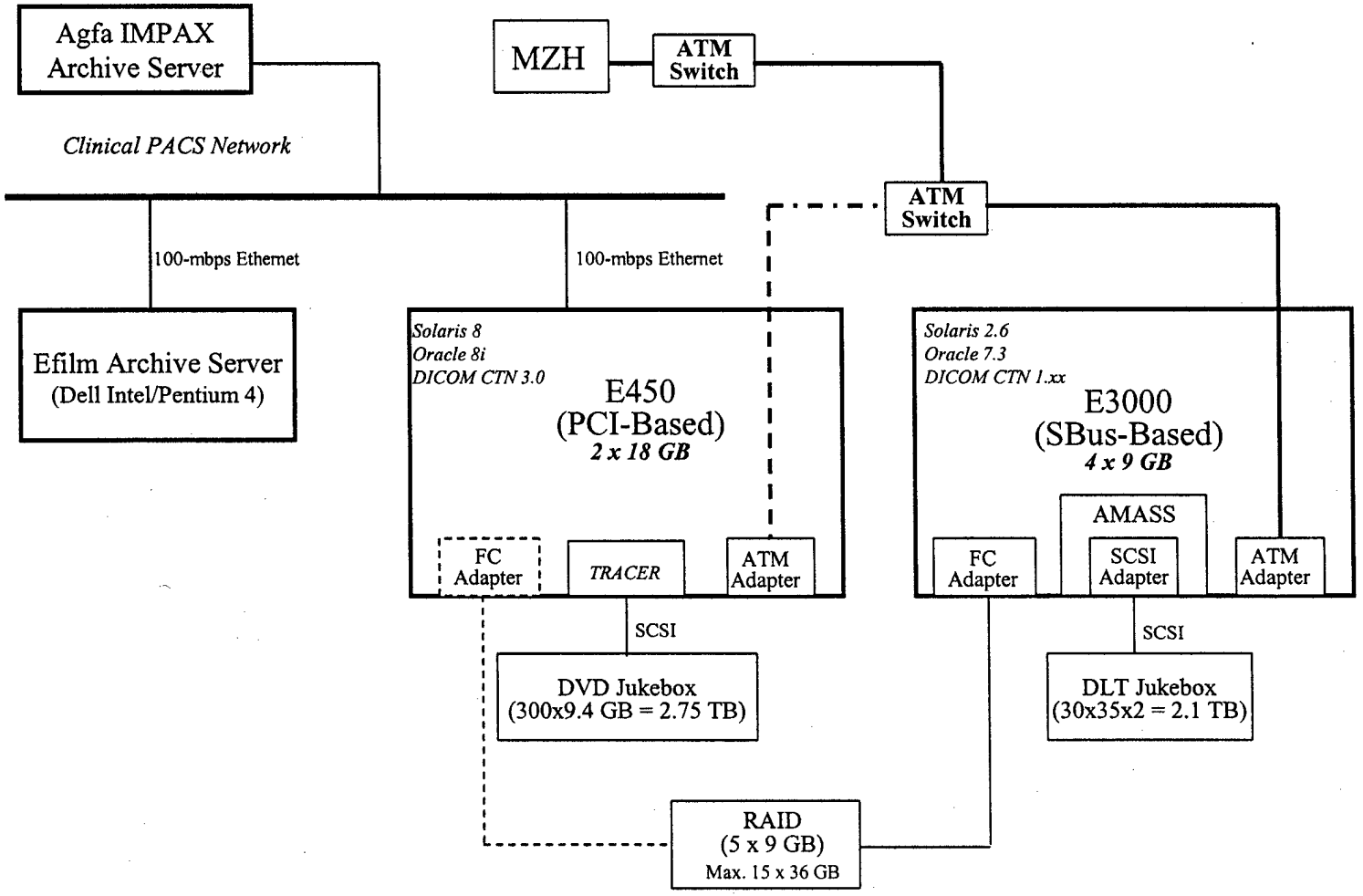

Figure 1 Configuration of the MMIA system. The E450 and #3000 computer systems are both connected to the UCSF PACS network so that medical images can be received by MMIA or distributed from MMIA to any UCSF PACS component. The DVD jukebox is attached to the E450 computer, and the DLT jukebox and RAID device are both attached to the E3000 computer.

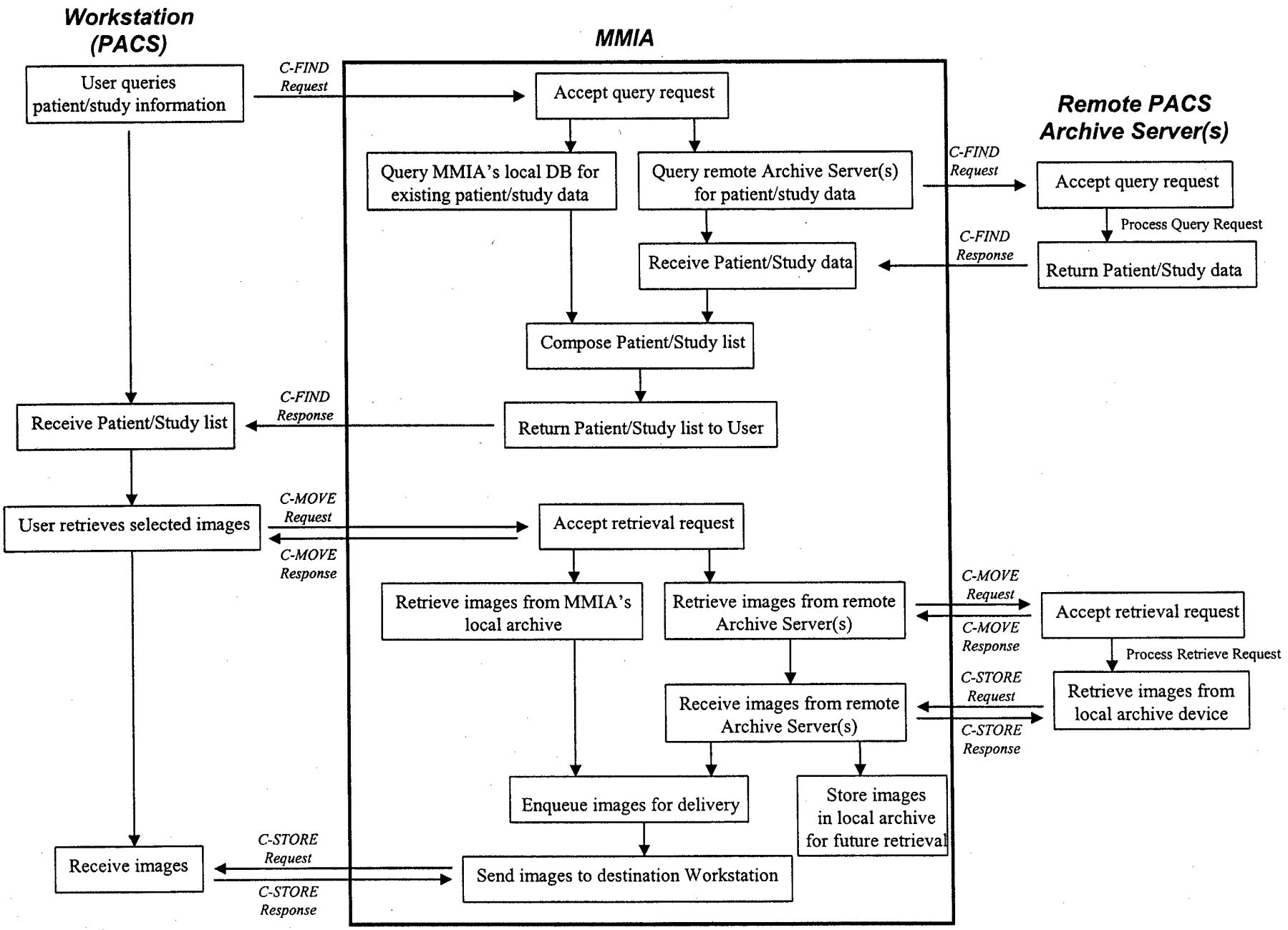

Figure 2 Functions of the MMIA broker

- Query and Retrieve Software: MMIA is capable to query patient examination information and retrieve selected examinations from both IMPAX and eFilm systems using standard DICOM C-FIND and C-MOVE services.
- Image Archive Software: MMIA accepts images to be transmitted from any DICOM-compliant imaging devices. These images are stored in MMIA's cache and long-term storage devices, which can then be retrieved at any DICOM workstations. Patient demographics and examination information are extracted from the header of these images, and are stored in the MMIA database in support of the query and retrieve operations.
- The implemented MMIA Query/Retrieve (Q/R) SCP software supports DICOM's two hierarchical Q/R information models: Patient Root and Study Root. Images can be retrieved either in the study or in the series level.
- A master patient table (MASTER.TBL) has been implemented in the MMIA database. This table provides necessary information for mapping a patient's identification (PATID) that is assigned differently by the individual medical facilities. The mapping mechanism is used to support MMIA's broker function (see next item), and a mapping algorithm is being implemented. The algorithm is based on identifying characteristics found in the DICOM image header of more than 15 modalities and models of digital imaging equipment. Three identifiers were present, namely the patient's name, the date of birth and the sex.
- A broker function is being implemented in the MMIA to allow query and retrieval requests from a user workstation (e.g., eFilm) be relayed to a third-party image archive (e.g., IMPAX). The response data from the requested archive server will be passed back to the requesting workstation via MMIA. These data (medical images and relevant examination information) can optionally be stored in MMIA's local archive device and database for future retrieval. Figure 3 illustrates the broker function of MMIA to process a query request based on DICOM's C-FIND service.

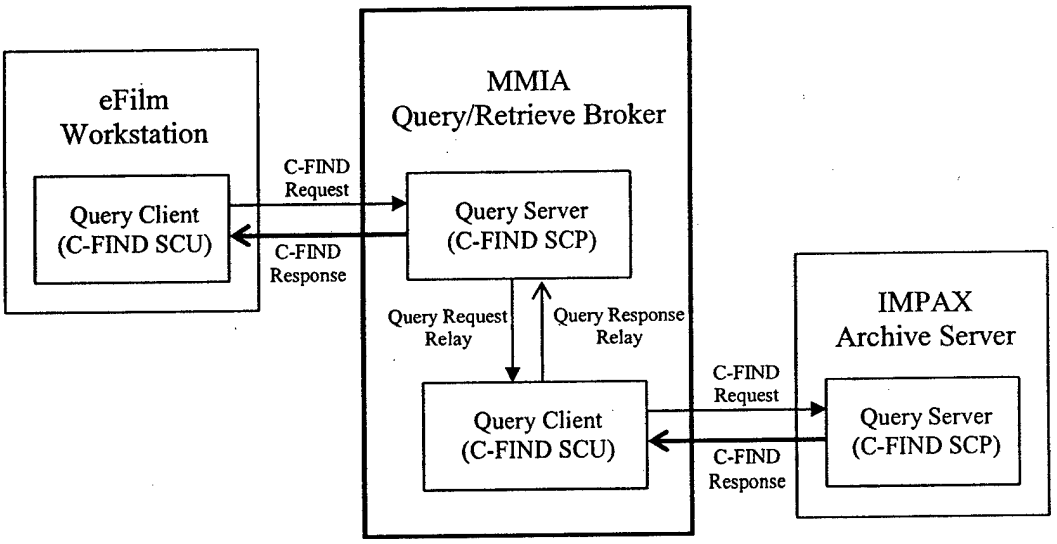

Figure 3. C-Find operations of the MMIA.

Establish MMIA/PACS connections (Task 4)

As seen in Figure 1, the MMIA is connected to both the Agfa clinical PACS and a research PACS archive, an eFilm from Merge Technologies, Inc. The clinical PACS is linked to the San Francisco VA PACS using a DICOM server. Studies from the VA can be pushed to this server, which in turn accepts DICOM query/retrieve operations from the Agfa PACS. The MMIA can also this query the server and retrieve studies that have been sent to it. The VA does not permit queries of its PACS from outside institutions.

Because of its connection the clinical PACS, the MMIA has access to images from all digital modalities including CT, MR, CR, DR, digital mammography, ultrasound, angiography, digital fluorographic spot images, nuclear medicine and PET. Equipment connected to the PACS originates from more than 10 manufacturers and many models of equipment. For example CR images are obtained from 2 vendor's equipment and 4 models. Access to the long-term archive of the clinical PACS increases the variety of equipment models that produced the images. DICOM services of the MMIA for images from all these modalities have been tested.

Thus the MMIA test cluster can broker between multiple archives including those where the patient identification is not identical. The master patient table (MASTER.TBL) implemented in the MMIA database provides necessary information for mapping a patient's identification (PATID) that is assigned differently by the individual medical facilities.

Research Accomplishments

- Utilization of industry-standard UDF file format in the archived images on DVD-RAM media provides transportability of the media, which consequently enables the archived images to be accessible by heterogeneous computer systems regardless computer hardware platform and operating system environment of these systems.

- The MMIA broker function allows multi-vendor image archive systems to be virtually interconnected via MMIA. Archived images and relevant examination information that are stored in the individual archive systems can be available as a single source from the MMIA broker.

- The varied DICOM information models (e.g., Patient Root query and Study Root query) adopted by individual PACS systems make MMIA more difficult in integrating the data and delivering them to the users in a single coherent view.

- Patient identification, commonly known as a patient's Medical Record Number (MRN) in a Hospital Information System (HIS), is usually assigned differently to a patient by the individual hospitals. Therefore, a patient with different MRNs in a multiple PACS environment could make the query and retrieve operations more complicated and less accurate. Use of a master patient table based on identifiers in the image header reduces chances of misidentification.

Reportable Outcomes

Presentation on the concepts and findings of this study has been made at several intra-institutional research seminars.

Conclusions

Implementation of a meta-manager as a system broker is necessary to overcome problems associated with patient and study identification, which frequently differ when multiple institutions are involved. While the DICOM standard is now nearly universally implemented on imaging equipment and in commercial PACS, information infrastructures at different institutions do not conform to any universal standards. Thus while it is possible to query a PACS using standard DICOM processes, identification of an individual can be difficult. The broker must not only relay these processes and their results, it must make sure that any relayed query for patient data is for the correct patient. For example, if at institution A, a patient is assigned Medical Record Number (MRN) **X** and at a different institution, that patient has MRN **Y** and a query is made through the MMIA from the first institution to the second, the broker must recognize that MRN discrepancy. This can be done by use of a master patient table within the MMIA, but population of this table is difficult. Thus we have determined that assuring the authenticity of the data with respect to patient identification is the most difficult aspect of broker implementation.

In the upcoming year we will complete the implementation and development of the MMIA software on the testbed. We will seek to change the Statement of work with regard to security since software encryption methods are now easily implemented and will be used rather than the Celotek hardware technology. We will also implement the failover technology to assure reliability.

The major components of the MMIA testbed are now in place. The testbed has been connected to the clinical PACS and DICOM queries between different PACS through the MMIA are possible. The MMIA can respond to DICOM queries, store studies in an optical archive, and send studies to a PACS. A database structure has been developed within the MMIA that can resolve patient identification problems although further development of this concept is necessary.